CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Simulation work of energy saving potential using adaptive cooling technique and dual fan dual duct system has been completed and described in detail. According to the results obtained from the research work, the conclusions can be summarized as the following:

1. Proposed technique called adaptive cooling technique coupled with dual fan dual duct system has been developed to effectively handle the intermittent cooling load. This technique uses adaptive comfort temperature (ACT) in air conditioned and naturally ventilated building as indoor comfort temperature set points during occupied and unoccupied hours, respectively. The simulation results show that the technique give 28.54% cooling load reduction and has annual energy saving potential as much as 255,960 kWh or equal to RM97,265 of cost saving.

2. An experimentally validated transient simulation model to model the building and simulate the cooling load characteristic in the building has been developed. Detail of the building was built according to the building construction detail and therefore, the model could be used as a tool to simulate and analyze the cooling load characteristic in the building for future development of the HVAC system.

3. As demonstrated in Chapter 4, the use of two indoor temperature set points for building with intermittent cooling load is found to have certain limit due to the mechanical limitation of single ducting system. Due to this, application of dual indoor temperature set points to accommodate occupied and unoccupied

hours, especially in hot and humid area, must be coupled with dual fan dual duct system.

5.2 Directions for Future Works

Opportunities to improve the recent works rely on but not limited to answer the following questions:

1. How to get optimum benefits from the adaptive cooling technique coupled with dual fan dual duct system?

   Control optimization on the dual fan dual duct system and combination of the adaptive cooling technique with dedicated outdoor air system (DOAS) is required to get optimum benefits from the technique. The effect of intermittent cooling load on energy consumption and control of the chilled water pump need more investigation.

2. What are the effects of response time of the HVAC system on the proposed system?

   Centralized HVAC system need more time to response the signal from the sensors compare to individual room air conditioner (RAC). Therefore, investigation on the effect of response time of the HVAC system is required to determine the system and indoor conditions during transient time.

3. In what conditions the proposed system must be considered and how to determine that conditions?

   Transient time during unoccupied mode to occupied mode leads to sudden increase on the cooling load. This condition somehow similar to on-off conditions which make the supply fan and chilled water pump consumes a lot of energy. If the room intermittently occupied and the time gap between occupied and unoccupied period is short, unwanted on-off conditions will occur on the system. Due to this, the range of occupancy pattern and the conditions where the proposed system can be applied should be determined.

5.3 Publications

Regarding to the work, two conference paper and one journal paper have been published. One additional journal paper has been submitted on February 2011 and it is still under review. The list of publication is as follow:

1. **Petrus T.B.**, S.I. Gilani, “Transient cooling load simulation of a mechanical workshop at UTP using TRNSYS”, international Conference on Plant Equipment and Reliability (ICPER) 2010, 15 – 17 June 2010, Kuala Lumpur, Malaysia

2. **Petrus T.B.**, S.I. Gilani, M.S. Aris, “Simulation of intermittent transient cooling load characteristic in an academic building with centralized HVAC system”, International Conference on Environment Science and Engineering (ICESE) 2011, 1 – 3 April 2011, Bali, Indonesia

3. **Petrus T.B.**, S.I. Gilani, “Transient cooling load characteristic of an academic building, using TRNSYS”, Journal of Applied Sciences, Vol. 11 (10): pp. 1777 – 1783, 2011

4. **Petrus T.B.**, S.I. Gilani, M.S. Aris, “Energy saving potential of adaptive cooling system in an academic glazed building with centralized HVAC system in tropical climates”, Energy Conversion and Management (under review)

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APPENDIX A

NEUTRAL TEMPERATURE AND COMFORT RANGE OF OCCUPANTS IN VARIOUS COUNTRIES [103, 122 - 135]

Author (Year)	Location	Type of buildings	Type of study	No. of subjects	RH%[2]	Comfort/neutral temperature (T_c)
Busch, [78]	Bangkok	N/a[2]	Field study	1100	N/a[2]	28.5 ET(NV[2])
de Dear et al., [123]	Singapore1	N/a[2]	Thermal Chamber	32	N/a[2]	25.4
de Dear et al., [124]	Singapore2	N/a[2]	N/a[2]	N/a[2]	35	27.6
				98	70	27.9
de Dear et al., [70]	Singapore3	MSRB[2]	Field study	583	N/a[2]	28.5 To[2]
Busch, [122]	Bangkok	Offices	N/a[2]	N/a[2]	50	27.4 ET[1]
Abdul Shukor & Young, [125]	Penang	N/a[2]	N/a[2]	N/a[2]	50	28.2
Karyono, TH, [126]	Jakarta	N/a[2]	Field study	596	N/a[2]	26.7 to (NV+AC)
Zainal & Keong, [127]	Johor Baru	Factory	N/a[2]	N/a[2]	18 -75	26
Abdul Rahman & Kannan, [128]	Shah Alam	Classrooms	N/a[2]	N/a[2]	54 -76	27.4
Khedari et al., [130]	Bangkok	Classrooms	N/a[2]	N/a[2]	70-80	27.2 at 0.2 m/s 28.3 at 0.5 m/s 30.3 at 1.0 m/s 31.2 at 1.5 m/s
Sapian et al., [129]	Kuala Lumpur	MS RB	N/a[2]	N/a[2]	Up to 90	N/a[2]
Wong et al., [131]	Singapore	MS RB	N/a[2]	N/a[2]	N/a[2]	28.9
Wong & Khoo, [132]	Singapore	Classrooms	N/a[2]	N/a[2]	N/a[2]	28.8
Sh. Ahmad & Ibrahim, [133]	Shah Alam	Classrooms	N/a[2]	N/a[2]	N/a[2]	27.6
Azah Ahmad et al., [134]	Putrajaya	Office	Field study	N/a[2]	50-54	N/a[2]
Sabarinah Sh Ahmad, [135]	Klang valley	Residential	N/a[2]	N/a[2]	N/a[2]	26.1
Hussein et al., [18]	Malaysia	Classrooms and Offices	Field study	559	49.5-75.3	23.1-25.6 (AC) 26-30.7 (NV)

1. The old ET scale matches DBT at 100% RH, whereas ET* matches DBT at 50% RH.
2. MS RB: Multi-storey residential building. To: Operative temperature Ta: Ambient temperature N/a: Not available NV: Naturally ventilated RH: Relative humidity